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The Solar Ocean Energy Liaison

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Solar OCEAN ENERGY Liaison

INCORPORATING
The OTEC Liaison

VOLUME 6, NUMBER 12
December 1982

THE FRENCH OTEC PROGRAM

After some uncertainties in 1980-81, the French Government has decided to go ahead with plans for design and construction of a prototype OTEC facility for Tahiti. This announcement was made by Philippe Marchand of CNEXO at the Ocean Energy Workshop which followed the Oceans '82 Conference in Washington DC September 23rd.

Marchand detailed the development schedule for the prototype five-megawatt land-based facility for the South Pacific island territory. Between 1982 and 1984, detailed site surveys will be made. Component testing, including cold-water-pipe options, will be undertaken on both open-cycle and closed-cycle power plants. Final

selection of open or closed cycle will be made in mid-1984.

The research and development phase will initially focus on open-cycle systems. Evaporators and condensers (both direct-contact and surface-contact) will be tested at a laboratory in Grenoble, France using fresh water which has been enhanced to simulate Tahitian waters in terms of dissolved gas and other properties. At this time little work will be done on closed-cycle heat exchangers, although the performance of enhanced titanium and aluminum surfaces will be tested.

The speaker noted that the decision to base the facility onshore was made because

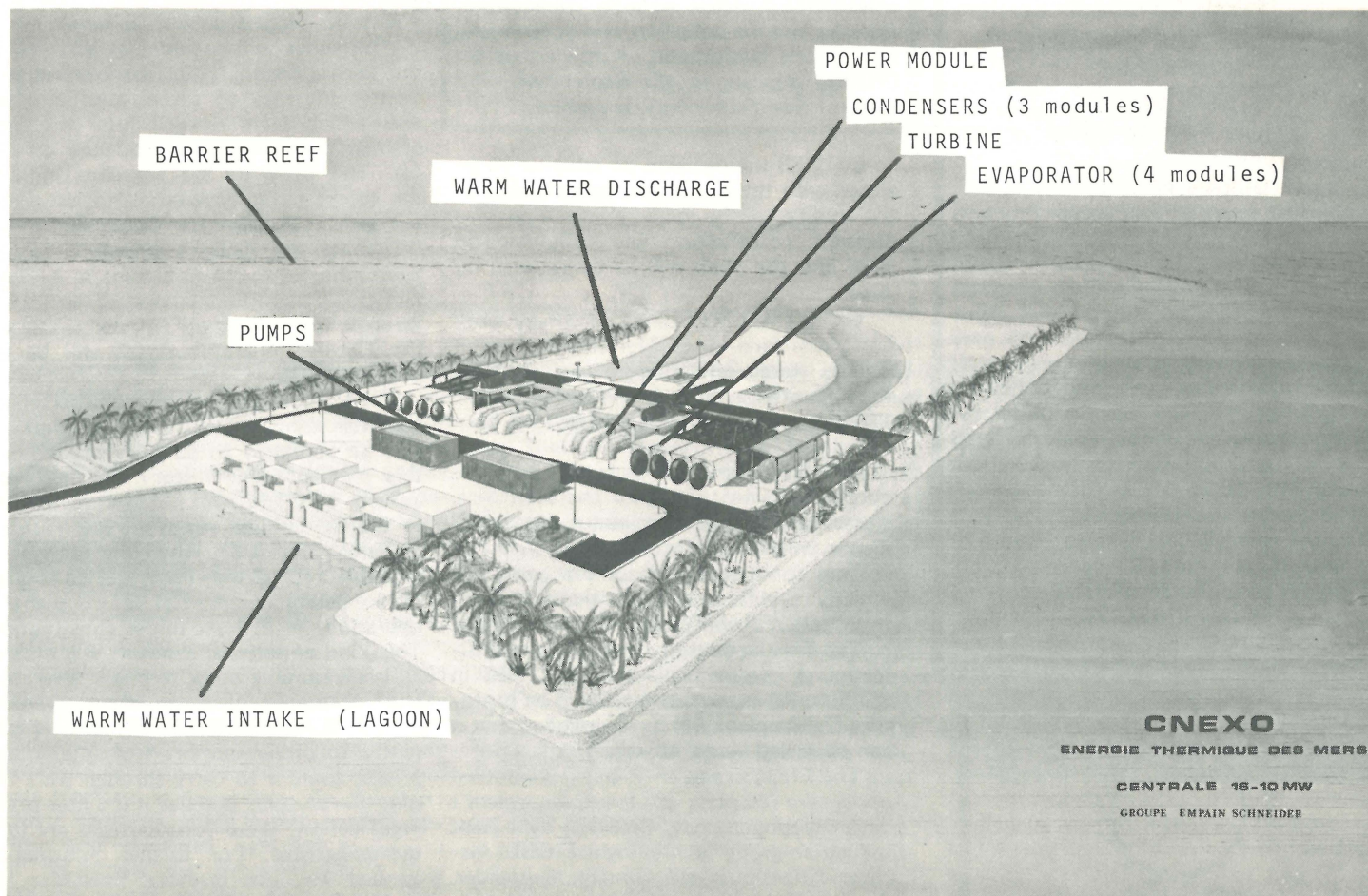
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(Note: The following is the third in a series of monthly articles covering recent OTEC-platform concept developments.)

GIBBS & COX SHELF-MOUNTED DESIGN

The final report on a 40-megawatt shelf-mounted OTEC Pilot Plant design was released earlier this year by Gibbs & Cox Incorporated. While generally optimistic in its conclusions concerning the viability of shelf-mounted platforms, the report noted that certain problems still existed in the deployment of a shelf-mounted system, especially with regard to cold-water-pipe (CWP) deployment. While the remaining problems are not considered fatal flaws, they do require further study.

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The illustration above is an artist's conception of the proposed 10-16-megawatt open-cycle OTEC plant designed for the island of Tahiti in French Polynesia.

Solar OCEAN ENERGY Liaison

INCORPORATING The OTEC Liaison

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THE SEA, INCLUDING:
OTEC
(OCEAN THERMAL
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WAVE - TIDAL - CURRENT
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of the advantages that option has over off-shore facilities. These include easier access for maintenance and repair, multiple-use capabilities [namely aquaculture and freshwater], and use as a cold source for cooling. Also, an onshore OTEC plant has the potential for transforming the prototype into an OTEC laboratory for testing and improving OTEC technologies.

The choice to look first at open cycle was made for several reasons. The open cycle operates more efficiently than the closed cycle. Also, biofouling is probably less important in an open-cycle plant. And finally, the open cycle is capable of producing large amounts of fresh water without desalting equipment and power losses.

Marchand mentioned that the five-megawatt open-cycle plant could produce 8,000 metric tons of fresh water (roughly two million gallons) per day. However if the open-cycle option does not appear feasible at the time when a decision has to be made, the closed-cycle will be selected.

A WORD ABOUT CNEXO

The Centre National pour l'Exploitation des Océans (CNEXO) is the French Government's ocean research and development agency. Since its founding in 1967, CNEXO has conducted numerous projects covering a wide range of subjects. These have involved OTEC, ocean minerals, aquaculture, fisheries, marine pollution, and ocean technology and instruments. A full article on CNEXO appears in the September 1982 issue of *Sea Technology* magazine.

By 1985 the decision on whether to go ahead with the design and construction of the facility will be made. If it is a positive decision, construction will commence in 1986 and the plant will be operational by 1988.

Up to this time, some site-survey work has been done. In 1981, biological water surveys were conducted to evaluate biofouling potential in deep and surface water. The bathymetric surveys have also been completed.

In 1983, seismic surveys will be conducted to evaluate seafloor characteristics. Water current and temperature measurements will be made over a 1,000-meter column for a minimum of one year. Sea surface conditions will be calculated from wind data and confirmed by at-sea testing.

The French development program is directed at commercialization of OTEC in the 5-to-40-megawatt market. The prototype Tahiti plant will be so designed that it can be scaled up to 40 megawatts.

The French program is being conducted under the auspices of the Government's oceanography agency, CNEXO, by a joint industrial group consisting of CGE Alsthom-Atlantique and Empain Schneider. An interesting footnote is that a division of this latter firm is the same one which built the original turbines for the French

OTEC pioneer Georges Claude in 1930. The name of this new OTEC group is ERGOCEAN.

Attendees at Marchand's presentation were treated to a 20-minute film following his talk. The entertaining film traced the history of OTEC from Claude's initial experiments to the present. Original film clips of Claude's ill-fated OTEC project in Cuba were included, and gave some interesting insight into the personality of this determined pioneer.

OTEC FEATURED IN PLANNED TELEVISION SERIES

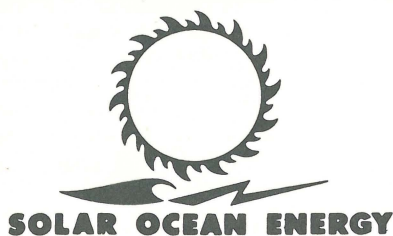
An hour-long television program on ocean energy is one segment of a nine-part documentary series which will examine man's historical and future relationships with the sea. The series, entitled *The Blue Revolution*, will require nearly five years and at least two million dollars to produce, and will be comparable to such classics as *Civilization* and *The Ascent of Man*.

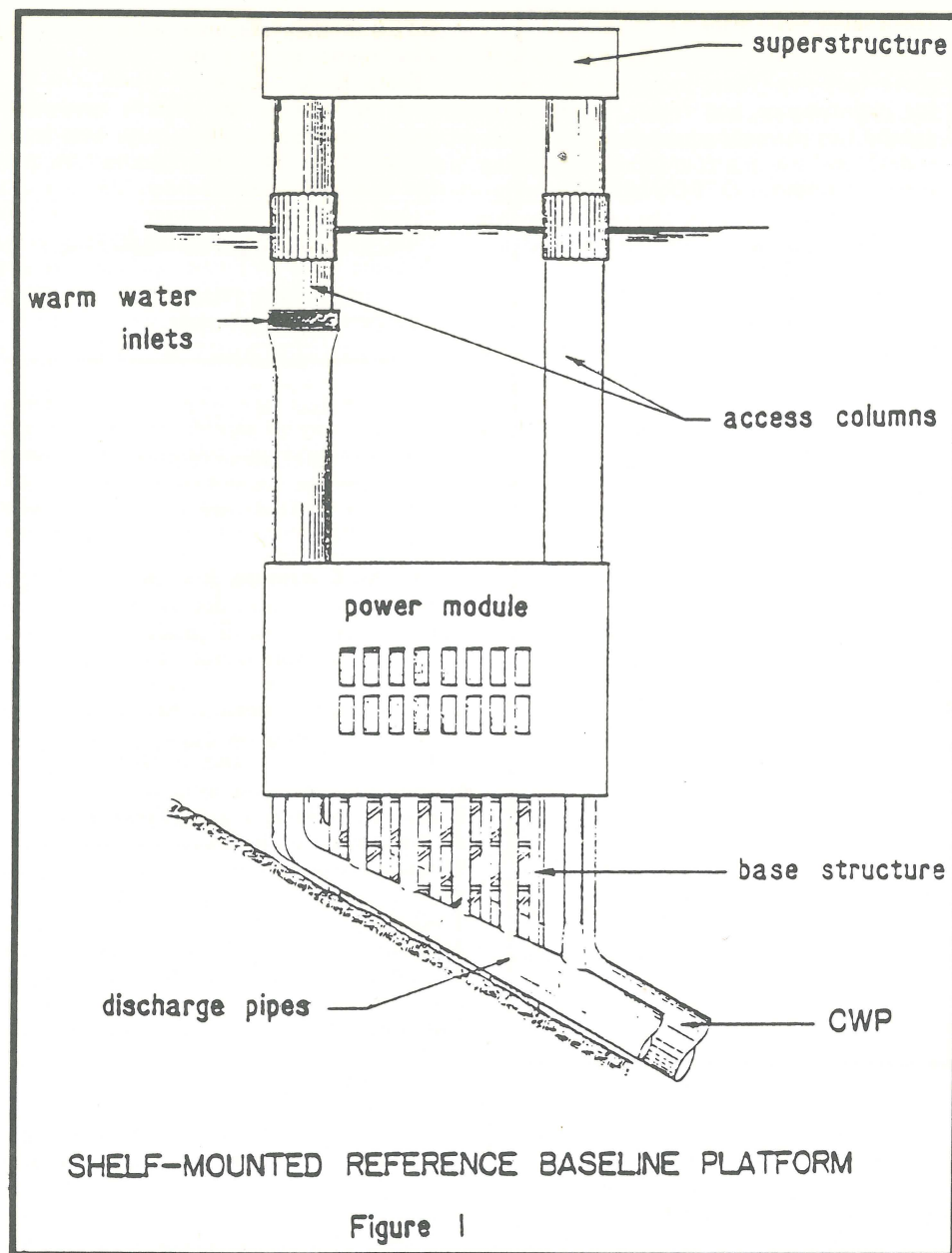
The Mare Nostrum Foundation, producer of the series, was established in 1980 as an avenue for providing essential information to the general public on the development and management of the oceans. The information gathered by the Foundation reaches the public through a nationwide lecture tour, publications, and educational films. *The Blue Revolution* represents its biggest project to date.

The series will include, in addition to the general opening and concluding segments, coverage of seven specific ocean uses which form or will form the basis of man's increasing dependence on the sea. The titles of the segments indicate the topics to be covered: "Harvest From the Sea", "Quest for Ocean Minerals", "Tapping the Ocean's Energy", "Drugs From the Sea", "The Oceans as a Waste Dump", "The Blue Highways", and "The Struggle for the Seas". Under "Tapping the Ocean's Energy", OTEC will be the primary focus.

Fred Naef and Bob Cohen, personalities well known to the OTEC community, will be acting in an advisory capacity on this segment. The history and technical aspects of OTEC will be covered, as well as the up-to-date status of the industry. Hopefully by 1987, when the program is scheduled for airing, there will be footage of an actual commercial OTEC plant in operation, or at least under construction. This kind of national exposure will provide an immeasurable boost to public awareness and acceptance of ocean-energy systems.

The Mare Nostrum Foundation is currently soliciting support from public and private sources to carry through with *The Blue Revolution*. Because it is a non-profit organization, these contributions are fully tax-deductible. For further information contact Mr. Luc Cuyvers, Executive Director, Mare Nostrum Foundation, PO Box 3223, Arlington, Virginia 22203, (703) 276-7722. ◀





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A series of trade-off studies was used to develop a final detailed optimum design for the shelf-mounted plant. The major top-level design requirements were given as baseline parameters for the overall study. The plant was to have a 40-mega-watt average annual electric output transferred to shore by submarine cables. The plant was to be deployed off Puerto Rico, use Lockheed PSD II closed-cycle power-system components, and be designed to withstand a 100-year storm.

Initial trade-off studies were made based on the following variables: power-module size and arrangement, module location within the platform system, module structure versus water depth, site selection, and platform configuration. In the first-phase trade-off, three power-module options were identified, each with its own set of advantages and disadvantages. A final decision on the module selection was thus deferred to the next phase of the trade-off study.

In evaluating options for module loca-

tion within the platform and the trade-off between power-module depth and platform depth, a detailed cost analysis had to be conducted. The underlying trade-off was that the deeper the module is in the water, the lower the wave and current forces, and thus the lower the cost of the tower-support structure. However, as the module depth increases, the cost of the module structure increases due to increased hydrostatic pressure. The trade-off then becomes one of cost of tower and piles versus cost of power-module structure.

The cost analysis was conducted using each of the three power-module options, located at several different positions within the platform in two arbitrarily-chosen water depths (250 and 500 feet). Based on the results of these trade-off studies, a module was selected in which the heat-exchangers are grouped into eight groups of eight, stacked two high. The analysis showed that the least-expensive platform system would be located in 250 feet of water with the top of the module 75 feet

below the surface.

Once the general site selection was completed, a more-detailed study of module depth versus platform depth was made to select the optimum specific site. Of six potential sites around Puerto Rico, two were found to be better suited to shelf-mounted OTEC plants. These are Punta Tuna and nearby Punta Yeguas. The latter was selected as the best site due to its proximity to port facilities at Puerto Yabucoa.

A refined depth-sensitivity analysis was then performed to determine the cost impact of relocating the platform in slightly deeper water than the 250 feet arbitrarily selected in the previous trade-off so as to reduce the possibility of wave breaking. Locating the platform in 313 feet of water with the top of the power module 150 feet below the surface was found to be the lowest-cost option.

With the platform site and module size and arrangement selected, a brief trade-off study was made to select an overall platform configuration. Two basic configurations were examined: the self-floating jacket and the jack-up platform. The self-floating-jacket type was further subdivided into three separate configurations: a single unit with the power module included as part of the structure, a single unit with a separately-deployed module, and a double-tower configuration with a separately-deployed module.

A subcontractor was enlisted to perform a further analysis from a deployment standpoint, since experience in the offshore oil industry has shown that deployment techniques tend to drive platform configuration. The trade-off study concluded that a jack-up configuration would offer the greatest flexibility at the least expense. This configuration formed the basis for the conceptual-design phase of the shelf-mounted-platform study.

In conceptual-design Phase I, the standard jack-up configuration (and a modified version) were found to be unfeasible because of instability and loading problems. Moreover, the risk involved in designing a 30-year-life jack-up platform, when the oil industry uses such a design only for short-term operations, further substantiated the final rejection of this option.

A conceptual-design Phase II was then undertaken to re-examine the steel-jacket option. Although this configuration offered excellent structural integrity and more-or-less standard deployment concepts, it lacked the flexibility of the jack-up configuration. Furthermore, the cost of the steel "jacket" to contain the power module seemed to be extravagant. A re-configuration was necessary to incorporate the best features of both concepts.

Due to the difficulties involved in handling a large structure on a 30-degree slope, separate deployment of the base of the structure was considered essential. Separation of the base and power module during deployment would also facilitate redeployment of the power module if nec-

COST SUMMARY

Gibbs & Cox 40-megawatt Shelf-Mounted Platform
Reference Baseline

DESCRIPTION	COST (\$ millions)
PLATFORM SYSTEM	
Hull Structure	59.86
Platform Support	7.71
Outfit and Furnishings	8.84
Assembly Support	0.74
Seawater Systems	6.79
Cold-water Pumps and Motors	4.34
Warm-water Pumps and Motors	4.46
Biofouling and Corrosion Control	2.65
SUBTOTAL	95.39
COLD WATER PIPE SYSTEM	
Pipe system	31.24
Screen	0.54
Pipe/Hull Transition	0.75
SUBTOTAL	32.53
POWER SYSTEM SUBTOTAL	86.04
ENERGY TRANSFER SUBTOTAL	12.48
10% MARGIN ON PLATFORM AND CWP SYSTEMS	12.58
TOTAL ACQUISITION COST	239.34
ADDITIONAL COSTS	
Acceptance Testing	4.01
Deployment Services	94.40
Facilities	15.19
Engineering and Detail Design	16.90
SUBTOTAL	130.50
TOTAL CONSTRUCTION/DEPLOYMENT COSTS	\$369.84 Million
COST PER KILOWATT	\$9,250/KW

essary. A smaller superstructure and smaller support legs were also determined to be advisable, as they would put less of a load on the base. Using these parameters, the final configuration shown in Figure 1 was developed.

As noted earlier, the overall platform is situated in 313 feet of water, with the top of the module at a depth of 150 feet. Two 22.5-foot-diameter fiber-reinforced plastic (FRP) warm-water intakes extend up 110 feet to a depth of 40 feet below the surface. The superstructure is supported by two 25-foot-diameter steel columns extending from the top of the module to 50 feet above the water surface. The module and superstructure rest on a base that also incorporates the cold-water and discharge ducting.

The platform base structure consists of steel tubular members welded together to form a truss or frame on which the power module rests. The power module will be deployed as a self-floating unit which ballasts down to the base once on-site.

The two relatively-small-diameter access/support columns act to provide required waterplane area during deployment and as routes for personnel and equipment transfer between the module and the superstructure once installation has been completed.

(Any readers who would like to submit information for inclusion in this series of articles on OTEC platforms should call or write Philip Haring at OE. This is an open-ended series covering technical and economic aspects, and will continue as long as information continues to come in.)

Cold-water-pipe-design trade-off studies were also conducted. The CWP is about 5700 feet long, of buoyant FRP/foam sandwich construction, pinned to the bottom by a pile-anchored steel jacket (truss) support.

All the construction/deployment procedures follow state-of-the-art offshore-industry practices. No unconventional or unavailable systems or procedures are used. The entire process, with the exception of base installation, is reversible should re-deployment be necessary or desirable.

The total estimated cost of acquisition and deployment of the 40-megawatt Shelf-Mounted Reference Baseline configured for the Lockheed PSD II power system would be \$369.8 million in FY '81 dollars, or \$9,250 per kilowatt based on a net power output of 40 megawatts. A cost breakdown for the plant and components is provided in Table 1.

The character of shelf-mounted plants

is such that they are very site-specific in design. The design concept presented in the Gibbs & Cox baseline study can be applied to other sites, but site-specific environmental parameters may induce a large deviation from the baseline in the design and cost variables.

US GOVERNMENT PROCUREMENT INVITATIONS AND CONTRACT AWARDS

Listed below are procurement invitations and contract awards related to OTEC in particular and ocean resources in general culled from the Commerce Business Daily. This is not to be construed, however, as a complete list.

Oct 25: Continued Research in Atlantic Oceanography: Contract N00014-82-C-0019 (no RFP), for \$1,808,175, awarded to the Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543. Office of Naval Research, 800 North Quincy, Arlington, Virginia 22217.

Oct 25: Collect and Analyze Oceanographic and Environmental Data From the Beaufort Sea With a View Toward Assessing Impact on Performance of Underwater Weapons: Negotiations are to be conducted with Science Applications Incorporated, 1200 Prospect Street, PO Box 2351, La Jolla, California 92038, as a result of their unsolicited proposal. Contract Negotiator C. W. Wentling, (202) 394-1477. Naval Surface-Weapons Center, Silver Spring, Maryland 20910.

Oct 26: Investigation of Flow Regimes of Sea Straits of the Southwest Pacific Ocean Utilizing Satellite Remote Sensing Imagery in Concert With Available In Situ Field Data: Negotiations are being conducted with SeaSpace, 5360 Butte Avenue, San Diego, California 92122. Contract Negotiator C. Davis, (202) 696-4510. Office of Naval Research, 800 North Quincy, Arlington, Virginia 22217.

Nov 3: Continue Support of the Naval Ocean Research and Development Activity (NORDA) Ocean Measurements Program Through Studies of Upper Ocean Structure: Negotiations are to be conducted with Science Applications Incorporated, 1710 Goodrich Drive, McLean, Virginia 22102. Contract negotiator Mark Thomas, (202) 696-4510. Office of Naval Research, 800 North Quincy Street, Arlington, Virginia 22217.

Nov 29: Verify and Improve Numerical Simulations of the Mixed Layer and Marine Boundary Layer in Various Regions of the Ocean: Negotiations are to be conducted with Science Applications Incorporated, 2999 Monterey Salinas Highway, Monterey, California 93940. Contract negotiator Mark Thomas, (202) 696-4510. Office of Naval Research, 800 North Quincy Street, Arlington, Virginia 22217.